Strobic Air Corporation

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TECHNICAL APPLICATIONS BULLETIN

Direct drive vs. belt drive fans for roof exhaust systems

An objective look at both technologies

Centrifugal fans such as this complex installation are highly susceptible to inlet and outlet system effects, with corresponding losses in performance efficiency.

There seems to be an age-old argument whenever the relative merits of direct drive roof exhaust fans vs. their belt-driven counterparts are discussed. While each of these technologies has its place in many specialized applications, our position is—and always has been—that belt driven centrifugal fans cannot be compared favorably with direct drive fans for most roof exhaust installations where Tri-Stack® systems are employed. In other words, the few advantages that belt drive systems offer (and we will discuss those here) are far outweighed by the many advantages that direct drive motors in Tri-Stack systems provide. This application bulletin will present an objective comparison for you; we hope it will be useful in your decision making process.

According to the *Fan Handbook*, Chapter 7, a centrifugal fan "…consists of a fan wheel and a scroll housing plus such accessories as the inlet cone, the cutoff, and the various supports for the housing and for the drive arrangement (motor, pulleys, bearings, and shafts)." The *Handbook* points out that most centrifugal fans are belt-driven since belt drive offers advantages of "less costly, higher speed motors… precise control of fan speed for required air volume and static pressure is possible…and speeds may be adjusted in the field with pulley changes." However, the *Handbook* also points out that "*direct drive is preferable whenever possible*," citing advantages (particularly in small sizes) of "lower costs for accessories such as supports, pulleys, bearings, and shafts." The *Handbook* also states that "up to 10% loss in brake horsepower may be consumed by belt drives; and, new belt stretch requires readjustment for added maintenance costs." A mixed flow impeller exhaust fan (Tri-Stack) mounted to a simple mixing plenum retains the same precise control of air volume and static pressure by modulating the amount of air exhausted from the building without the inconvenience of upgrading belt drive components and rebalancing the exhaust system. This saves time and money for the owner and contractor at the time of installation and commissioning.

The centrifugal fans on this roof (with their housings removed) require monthly drive belt inspection, according to ANSI Z9.5 Standards. Mandatory maintenance adds costs and downtime, while possibly exposing workers to dangerous fumes.

Direct drive fans exhibit substantially inherently lower vibration characteristics than belt driven centrifugal fans which will be explained later. A properly designed mixed flow impeller fan is ideally suited to take advantage of the higher reliability of a direct drive configuration.

The old adage of "fewer moving parts result in fewer breakdowns" is true. A direct drive system has one potential point of failure—the motor. A typical belt drive system has *five potential points of failure* in its drive system alone. These include belts, motor, shaft and pillow block bearings, and flexible duct connections.

Energy loss with belt-driven fans

Most centrifugal-type roof fan installations that are used in place of mixed flow impeller fans incorporate belt drives. Whenever there is an intermediary (transmission) between working machinery there must be a loss attributed to that exchange. A belt drive is no exception. Even at their most efficient design, performance, and configuration (properly installed, maintained, and adjusted) a typical belt-driven centrifugal fan loses up to ten percent of its energy. That's a minimum; in most cases, these fans lose even more energy because of improper alignment of shafts, pulleys, pillow blocks, and motors.

Maintenance effort and costs

One of the major complaints of many centrifugal fan users is the maintenance associated with these fans, whether it is for weekly inspection of bearings or drive belts and/or monthly/quarterly replacement of those items. For practical purposes, direct drive centrifugal-type fans are not feasible in many applications where mixed flow impeller fans might be used as replacements. Consequently, maintenance must be given serious consideration since it can have a substantial negative influence on system operating costs.

Another major expense encountered at many facilities with centrifugal-type roof exhaust systems concerns costs for rooftop "penthouses," enclosures built essentially to protect maintenance workers during inclement weather when changing drive belts, shaft bearings, or motors, for example. Use of penthouses also exposes those workers to possible toxic and/or noxious fumes while performing their maintenance tasks. Penthouses can be expensive, too; and other accessories for centrifugal-type fans (to attenuate vibration and noise, for example) further add to these costs. Because of their flexible duct connectors that are maintenance prone and usually required to attenuate vibration, penthouses for centrifugal-type fans can become dangerous environments for workers.

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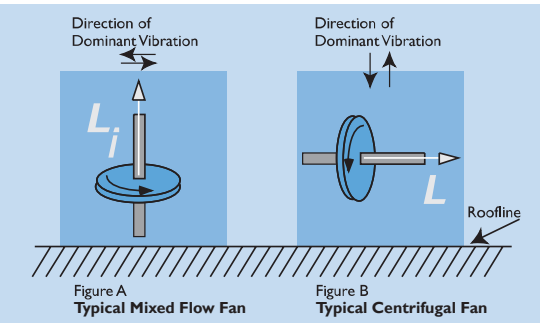
Faster installation, lower costs, less downtime

On the other hand, most mixed flow impeller systems are virtually maintenance-free (there are no belts, pulleys, or pillow block bearings to maintain or other accessories typically associated with centrifugal fans). The need for rooftop penthouses to protect maintenance personnel under adverse conditions is also eliminated. Consequently, installation costs are substantially lower. Tri-Stack systems are composed of three individual modules, specially designed to speed and simplify installation while reducing installation costs. As a result, mounting Tri-Stack fans directly on the roof is fast, and there's no need for expensive construction equipment and helicopters that may require building evacuation. Typical installation can be accomplished in less than two hours, with minimal—or no—disruption of work schedules causing wasteful and expensive downtime. Tri-Stack systems are also easily retrofitted onto existing roofs with minimal effort.

Maintenance comparisons

As previously mentioned, routine maintenance can be troublesome and costly with traditional centrifugal-type belt-driven fans. Other maintenance concerns for centrifugal-type fans include their bearings—shaft, motor (and pillow blocks, in many cases); in most centrifugal-type fans bearing lifetimes are rated substantially less than mixed flow impeller fan bearings. This is mainly due to vibration issues, which are also responsible for premature failure of belts, spring isolation mounts, and flexible duct connections—more maintenance headaches! **For specific details on motor bearing lifetimes, refer to our Technical Applications Bulletin No. 102 on bearing life comparisons.**



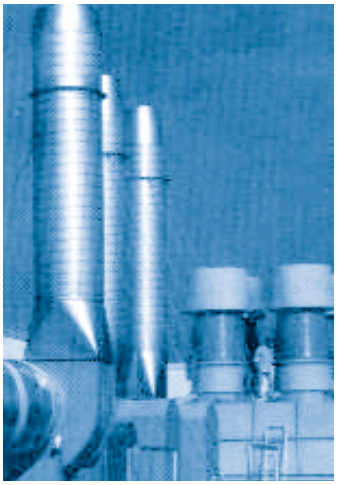
The typical mixed flow fan transmits vibration parallel to the roofline. The typical centrifugal fan transmits vibration directly down to the roof.

Vibration effects

When comparing vibration characteristics of centrifugal-type fans with mixed flow impeller fans, consider that most centrifugal fans generally conform to an industry standard of 2.0 mils vibration peak-to-peak. This is *four times* higher than the maximum vibration level of mixed flow impeller fans at 0.5 mils peak-to-peak. Vibration can be broken down into two components: radial and axial. If you look at vibration caused by dynamic balance, radial vibration is *always higher* than axial vibration. A mixed flow impeller system's radial vibration parallels the building roofline. As a result there is a substantially lower axial component of vibration forced vertically onto the roof. Conversely, in a centrifugal system, the high radial component of vibration (typically 2.0 mils), is forced directly down *onto* the roof.

Let's quantify these statements briefly: The *maximum* allowable vibration level of a typical mixed flow impeller fan is 0.5 mils. Many times the actual peak vibration is lower. The radial component of vibration is 0.5 mils. The axial component of vibration is 0.15 mils. This vibration is transmitted into the building or ductwork. As a result a mixed flow impeller fan can be hard mounted to the roof system and ductwork without concern for vibration problems. Most centrifugal fan manufacturers balance to a standard of 2.0 mils. Remember, due to the configuration of typical belt drive fans *the radial component of vibration is forced directly down onto the roof.* This is 2.0 mils of vibration moving vertically up and down on the roof structure, hence the need for spring bases and flex connectors; that means higher initial costs for centrifugal fan systems. Worse yet, the actual wear and tear can lead to chronically poor system performance and potentially unsafe working conditions.

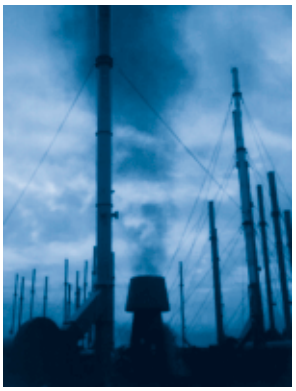
Mixed flow impeller systems are also quieter, use less energy, and provide enhanced performance with faster payback over traditional belt drive centrifugal fans. A typical reduction of $.44 per CFM at $.10/kilowatt-hour provides an approximate two year R.O.I. Energy consumption for mixed flow fans is about 25% lower than centrifugal fans with substantially reduced noise levels, particularly in the lower octave bands.



Four low-profile BS-5 Tri-Stack systems provide 40,000 CFM each; their counterpart belt-driven centrifugal fans on the left are more than twice as tall.

Tall exhaust stacks connote air pollution

When making an objective comparison between these two technologies, there's another issue that might require consideration, depending upon circumstances. That is, the aesthetics of stack height. Tall exhaust stacks on a building's roof are usually perceived as "pollution generators," even if they're only emitting steam. No one likes to look at them anyway. With centrifugal-type systems, there is no way to eliminate these tall stacks on the roof if all of the performance objectives of the exhaust system are to be achieved. Obviously the lowest possible profile not only eliminates the "smoke stack" look and negative connotations perceived by many people, but may actually be required (in some jurisdictions) to conform to applicable ordinances. More and more communities are restricting total building height and, by inference, the height of exposed stacks and other rooftop equipment. Elimination of tall, unsightly stacks (which are either prohibited by code or undesirable) is also a worthwhile goal.



Tri-Stack's vertical plume exhaust is clearly evident here, among a virtual "forest" of dedicated and guyed centrifugal fan stacks. The single Tri-Stack system handles nearly the same volume as all of the tall stacks combined.

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